**UCRL-JC-126200 Abs**

# FUSION RESEARCH: THE PAST IS PROLOGUE*

Richard F. Post

Lawrence Livermore National Laboratory
Livermore, CA 94550 USA

At this juncture fusion research can be viewed as being at a turning point, a time to review its past and to imagine its future. Today, almost 50 years since the first serious attempts to address the daunting problem of achieving controlled fusion, we have both an opportunity and a challenge. Some predictions place fusion research today at a point midway between its first inception and its eventual maturation - in the middle of the 21st century - when fusion would become a major source of energy. Our opportunity therefore is to assess what we have learned from 50 years of hard work and use that knowledge as a starting point for new and better approaches to solving the fusion problem. Our challenge is to prove the "50 more years" prophesy wrong, by finding ways to shorten the time when fusion power becomes a reality. Must it really take a century to solve the fusion problem?

The thesis will be advanced that in the magnetic confinement approach to fusion "open-ended" confinement geometries offer much in responding to the challenge. Open-ended systems, as exemplified by systems employing the magnetic mirror effect, have many potential advantages over "closed" systems such as the tokamak. Among these is the total control that can be exercised over MHD instability modes through the use of confining fields with favorable curvature. Another is the ability to establish and control electric potentials within the plasma, to suppress instabilities, to enhance confinement, and to direct the flow of escaping plasma.

For the fusion researcher a major advantage of open systems is that, owing to their theoretically and experimentally demonstrated ability to suppress plasma instabilities of both the MHD and the high-frequency wave-particle variety, the confinement becomes predictable from "classical," i.e., Fokker-Planck-type analysis.

In a time of straitened budgetary circumstances for magnetic fusion research now being faced in the United States, the theoretical tractability of mirror-based systems is a substantial asset. First, one can use theory and existing computer codes to analyze new variants, with confidence that the predictions will closely model reality. Second, owing to the fact that the scaling laws for open-ended systems are very different from those associated with closed systems (where turbulence is omnipresent), significant results should, in many cases, be obtainable from smaller experiments, using theory to project to fusion-relevant sizes.

Looking back over the history of magnetic fusion research it is not difficult to discern how closed systems, such as the tokamak, came to dominate the research scene. Their relative simplicity, their appealing empirical scaling laws (confinement time increasing as the square of the plasma radius) and their theoretical intractability (which forced an empirically based approach to progress) led to larger and larger facilities. The central theme of the tokamak campaign was, and still remains, "better confinement, hotter temperatures, and closer approach to the Lawson Criterion for plasma ignition." In a time of uncertainty as to the viability of the concept of magnetic confinement of hot plasmas, this theme was certainly a valid one. However, in seeking to achieve the ultimate goal of fusion research, that is, "to generate power at a competitive cost, and with superior environmental and safety characteristics as compared to other energy sources," that theme is too simplistic. We must instead cast a wider net.

If "casting a wider net" includes another look at open-ended systems, (which now represent only a tiny portion of the fusion effort), we must also be realistic in recognizing the primary reason for their decline: end losses. Both an asset and a liability, the end loss channel of mirror systems has been a constant concern since the idea was first broached. New mirror-based approaches must be mindful of this past history, and of its importance.

In our search it is also necessary to keep an open mind as to the forms that mirror-based fusion power plants might take. For example, we can look to the high-energy physics community for one possible model. This community has shown the feasibility of constructing large and complex particle accelerators using superconducting magnets, vacuum chambers and complicated particle-handling technology, housed in underground tunnels that are 20 or more kilometers long. In the paper, building on earlier work (1,2), we will discuss some illustrative examples of mirror-based fusion power systems resembling long "linear colliders."

The examples will also illustrate another point: By attending to the efficiency of heating and energy recovery of fusion power systems it should be possible to operate them in a "driven" mode, the confinement time requirement for which is much less demanding than that for ignition. In this way some of the burden of achieving long confinement times is removed, being replaced by a well-defined technological task: designing better injectors and higher efficiency direct converters. The gas turbine is a mechanically based example of this approach.

It is not the intent of this paper to present detailed proposals for next-generation experiments in magnetic fusion research, but rather to encourage a return to the ambiance of an earlier era of fusion research, when innovative thinking and a spirit of scientific adventure prevailed. I believe that in that way we can realistically build a new era of fusion research, an era that would be firmly undergirded by the scientific and technological foundation that was laid in fusion's first half-century.

*Work performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

References:

1) R. F. Post and J. F. Santarius, Fusion Technology, 22, 13 (1992)

2) R. F. Post and D. D. Ryutov, in Proceedings of 1st Symposium on Current Trends in International Fusion Research, Washington D. C., 19-23 September, 1994 (in press)